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PRODUCTIVITY AND COST OF CONVENTIONAL UNDERSTORY BIOMASS HARVESTING SYSTEMS

by

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SUMMARY:

Conventional harvesting equipment was tested for removing understory biomass (energywood) for use as a fuel at a pulp mill. A one-pass harvesting system which removed the energywood along with the pulpwood was found to have harvesting costs for the energywood which were insensitive to the level of energywood present. A preharvest system of producing energywood exhibited high harvesting costs when biomass levels were low, but moderated as biomass levels increased.

Introduction

The harvest of woody biomass for hog fuel (energywood) is becoming increasingly important in the forest industries. The American Pulpwood Association (Kluender 1980) reported that fossil fuels accounted for 52% of the energy required by pulp and paper mills. Current estimates are that wood provides 75% of the fuel in these mills. In fact, wood accounts for 2% of the nation's fuel (OTA 1980). Moshofsky (1980) reports that wood use for energy is increasing at an annual rate of 10%. Much of this increase is provided by the harvest of energywood by operations totally dedicated to the harvest of wood for energy (Stokes et al. 1984).

To enter into an energywood harvesting operation a company must have an idea of the conditions under which it is economically feasible to carry out the operation. Several firms in the South are considering or have entered into the harvest of understory biomass as a hog fuel source. Our cooperator in this study was Scott Paper Company who has recently increased their consumption of energywood at their Mobile, AL, operations. The major concern in such an operation is the amount of understory biomass that must be present for the operation to be economically feasible. Understory biomass can range to levels as high as 60 green tons per acre on tracts that have not been prescribed burned. However, levels as low as 3 green tons per acre have been observed where prescribed burning is frequently practiced. This paper reports on a study designed to access the impact of understory biomass level on the cost of harvesting energywood.

Two types of systems for harvesting energywood were tested. In one system the energywood was harvested in a first pass through the stand, with the pulpwood being harvested in a second pass. This system is called the two-pass system. In the other system, the energywood and pulpwood were harvested simultaneously. This system is called the one-pass system.

In the one-pass system, feller bunchers felled the pulpwood and the energywood in one pass. The feller bunchers separated the trees into piles of pulpwood and energywood. Pine trees less than six inches in diameter at breast height and all hardwood constituted energywood. The equipment spread consisted of three feller bunchers, three grapple skidders, one twenty-two inch portable chipper, and one chainsaw. The grapple skidders made alternate drags of pulpwood and energywood. The energywood piles were skidded directly to the chipper. The slideboom on the chipper was used to feed the energywood into the chipper.

In the two-pass system the feller bunchers felled the energywood in a first pass through the stand. In the second pass the feller bunchers felled only the pulpwood. The equipment spread in the energywood pass consisted of three feller bunchers, three grapple skidders, and one twenty-two inch portable chipper.

The grapple skidders made drags of energywood to the chipper. The slideboom was used to feed the energywood into the chipper. After the pulpwood was felled, grapple skidders made drags to the same deck. The tops were removed and the pulpwood was cold decked. Only the portion of the study dealing with the energywood harvest will be discussed in this paper.

Methods

Five-chain-by-ten-chain test blocks in slash pine plantations were established in Escambia and Conecuh counties in Alabama. The plantations ranged in age from 17 to 23 years. Six test blocks were allocated to the two-pass harvesting system. Four blocks were allocated to the one-pass system. The four two-pass test blocks were paired with the first four one-pass test blocks. The blocks were in close proximity to each other, and on a very similar topographic position. The cruise method, which will be explained in this section, was used to verify that the blocks were of similar understory composition.

On each test block a deck was located at the midpont of a ten-chain side. The five acre blocks were of the same configuration to maintain average skid distances between the tests.

Eight ten-factor prism plots were established in each test block. At each point, energywood detected as "in" was tallied as hardwood or pine. For each hardwood tallied, 5.6 tons per acre of energywood was estimated. For each pine tallied, 5.2 tons per acre of energywood was estimated (Phillips and Saucier 1982). The basal area for pine and hardwood energywood was used to characterize the stand also. The various test blocks are described in Table 1.

Each test block was logged by one of Scott Paper Company's energy crews. The productive time was recorded for each piece of equipment, while logging each block, by Servis recorders mounted on each machine. The recorder disks were collected daily to obtain the productive time for each machine on each test block. Each truckload of energywood was weighed at the mill to determine the total tonage removed from the tract. From this data, production of energywood in green tons per productive hour was determined.

On the one-pass test blocks, the skidders and feller bunchers produced both pulpwood and energywood simultaneously. To properly allocate the amount of time the machines devoted to each product, the percent of time producing each product was estimated from a time study. The total productive time for the skidders and feller bunchers on each test block was recorded with Servis recorders. A detailed study of the feller buncher was also performed by using two stop watches to record the time spent on energywood and the time spent on pulpwood. Each feller buncher was studied in this manner for at least thirty minutes on each test block. With this data a percent of time was developed for felling energywood and pulpwood. The skidding time was similarly divided by counting the number of drags of energywood and pulpwood that were produced from each block. A ratio of productive time was allocated to each product based on these drag counts.

Production Studies

The average production of energywood in green tons per productive hour was calculated for each piece of equipment on each test block (Table 2). Regression techniques were used to analyze the relationship of production to volume of energywood per acre.

The feller buncher was the only machine that was significantly affected by the tonage of energywood present on the two-pass blocks (Figure 1). The regression equation was:

Feller buncher production in green tons/productive hour

= 6.33 + 0.205 (Green tons/acre)

The variable was significant at the 0.05 level with an R^2 of 79 percent.

This can be attributed to the manner in which the feller buncher was utilized. The feller buncher always built a full bundle for the skidder. In a low tonage stand, the feller buncher spent more time moving from one stem to the next than felling and bunching stems. Conversely, in a high tonage stand, production rates climbed because the feller bunchers did not have to travel as great a distance to fell a sufficient number of stems to build a full bundle for the skidder.

The grapple skidder production rate was not significantly affected by the tonage of energywood per acre. This was because the feller bunchers accumulated energywood into piles, which were sufficiently large for the skidders to maintain production. The insignificant differences in skidder productivity over the range of tonages of energywood tested must be further explained. The test block area and configuration was the same in each case. The deck was located in the same spot on each block to maintain the same average skid distances among the test blocks. Also, each test block was picked with one of the criteria being that the energywood be distributed uniformly over the block. The feller bunchers built large piles of energywood in low tonage stands as well as high tonage stands. The productivity of the skidders was a function of skid distance and tonage per drag. With the conditions stated above, regardless of tonage of energywood per acre, proportional numbers of equal size drags were made from the same skid distances. Thus, skidder production in tonage of green energywood per productive hour was not significantly different over the range of tonages tested.

The chipper production was not significantly affected by the tonage of energywood per acre. This is due to the fact that the skidders were able to feed the chipper at a rate that was not significantly different over the range of tonage of energywood tested.

It can be seen that production bottlenecks could occur with the two-pass system. When equal numbers of feller bunchers and skidders are used, a bottleneck occurs because the production of a skidder is higher than that of a fellerbuncher. This problem worsens with a reduction in tonage of energywood per acre. This is because the feller buncher production was significantly lower as tonage decreased, while there was not a significant reduction in skidder production. Production bottlenecks were eliminated between the skidders and feller bunchers by allowing the feller bunchers to complete a test block before skidding and chipping started.

Three skidders were used on these test blocks. Thus, no production bottlenecks occurred between the skidders and chipper. From the production data, it can be seen that the chipper was producing at a rate faster than that of the skidders in some cases. The bottleneck was eliminated because the skidders produced slightly ahead of the startup of the chipper and during the time the chipper was waiting for chip vans to be moved into position.

If this system was used exclusively in low tonage energywood stands, these low tonage tracts could be harvested at a faster pace than the high tonage tracts. This would create the need to move the system more often during a given time period.

The movement of the system, even though it is very mobile, can take appreciable amounts of time. The chipper has to be made road-ready. If the move is over ten miles, the skidders and feller bunchers should be hauled on a low boy trailer. Before production can start, a deck must be constructed for the chipper, and turn-around roads cleared for the trucks and chip vans. These processes are counterproductive and can be very costly.

Small low tonage areas within a high tonage tract can be harvested without an impact on the production rates. However, more intensive site preparation has been practiced in recent years. This has led to lower energywood tonages on this land. Therefore, the consideration of low tonage stands will become more important as the high tonage energywood stands are depleted. The one-pass system, which utilizes the tops of the pulpwood trees for energywood, has advantages over the two-pass system when viewed in this light.

In the one-pass system, the production rates can be misleading. The machine's productive time was calculated as outlined in the methods section. But, a part of the total energywood tonage produced in the one-pass system was produced in the pulpwood phase of production. The felling and skidding of the pulpwood tops was essentially free because they are moved with the rest of the pulpwood to the chipper. Therefore, production rates for felling and skidding energywood were driven up due to this improved utilization of the pulpwood tree (Table 1).

The feller buncher production was not significantly different over the range of tonages tested in the one-pass tests. This was due to the free tonage of energywood contributed by the pulpwood tops.

The grapple skidder production was not significantly different over the range of tonages tested. This was because the feller bunchers accumulated energywood into piles, which were sufficiently large for the skidders to maintain production.

The chipper production was not significantly different over the range of tonages of energywood tested. This is because the skidders were able to feed the chipper at a rate that was not significantly different over the range of tonages tested.

Cost Analysis

Cost estimates were prepared by the Engineering Research Project of the U. S. Forest Service, Auburn, Alabama. Initial price was the replacement cost of the machine (Watson and Stokes 1984).

A loaded labor rate of ten dollars per hour was assumed. The labor hours were calculated by dividing the utilization rate of the machine into the productive hours spent on each test block. The machine cost was calculated by multiplying the machine cost per productive hour by the productive hours spent on each test block. Thus, a total cost to harvest each test block was calculated.

The component cost of producing energywood in dollars per green ton was calculated for each piece of equipment on each test block (Table 3). Regression techniques were used to analyze the relationship of cost to the tonage of energywood per acre.

The feller buncher cost was the only cost that was significantly different over the range of tonages tested on the two-pass test blocks (Figure 2).

The regression equation was:

Feller buncher cost in dollars/green ton

= 8.84 - 0.130 (Green tons/acre)

The variable was significant at the 0.05 level with an R^2 of 81.7 percent.

The low production rates associated with the low tonage test blocks yield a high cost per green ton.

The cost per green ton for skidding was not significantly different over the range of tonages tested. Likewise, the chipper cost per green ton was not significantly different over this range of tonages.

There was a significant difference in the total cost per green ton, for the two-pass system, over the range of tonages tested. This difference can be attributed to the significant difference in the cost of felling the energywood.

Cost estimates were developed using regression techniques to predict cost in dollars per green ton from tonage of energywood per acre (Figure 3).

The regression equation was:

Cost per green ton with no moving costs

= 13.90 - 0.160 (Green tons/acre)

The variable was significant at the .05 level with an R^2 of 77.2 percent.

This cost estimate demonstrates the increasing costs associated with harvesting a low tonage energywood stand. These costs were driven up by the high cost of felling and bunching the energywood in low tonage stands. It must be pointed out that these costs are only for harvesting the energywood on each five acre test block. These costs do not include any trucking or deck preparation.

A second cost estimate was constructed that included a one hundred dollar moving and deck preparation cost for each test block.

To demonstrate the effect of moving and deck preparation on the cost estimates, several assumptions were made to arrive at a moving cost. To move the harvesting system and prepare the deck, a truck was needed for thirty minutes to move the chipper at a cost of $15.00. The chipper operator and a utility man were needed for two man hours at a cost of $10.00/man hour. A skidder and a feller buncher were used for one hour and fifteen minutes to clear the deck at a combined labor and machine cost of $65.00. With these assumptions a $100.00 cost was assigned to prepare a test block for harvest. It must be pointed out that the movement of the system in practice is often this frequent (Figure 4).

The regression equation for this cost curve was:

Cost per green ton with deck preparation cost

$$= 27.70 - 0.948 \text{ (green tons/acre)} + 0.0155 \text{ (green tons/acre)}^2$$

The green tons/acre variable was significant at the .01 level and the squared term was significant at the .05 level with an R^2 of 98.1 percent.

Again, no trucking cost was included. This curve demonstrates the ability of the high volume tracts to carry this additional cost.

In the one-pass system, the cost per green ton can again be misleading. The cost per green ton was calculated as outlined in the cost analysis section. But, a part of the total energywood tonage produced in the one-pass system was produced in the pulpwood phase of production. The felling and skidding of the pulpwood tops was essentially free because they are moved with the rest of the pulpwood to the chipper. Therefore, costs per green ton for felling and skidding energywood were driven down due to this improved utilization of the pulpwood tree (Table 3).

The feller buncher cost was not significantly different over the range of tonages tested. This was due to the free tonage of energywood contributed by the pulpwood tops.

The grapple skidder cost was not significantly different over the range of tonages tested as were the chipper costs per green ton.

Likewise, the total cost per green ton was not significantly different over this range of tonages. The average cost per green ton of the one-pass system was six dollars and forty-four cents.

A fifty dollar deck preparation cost was added to the one-pass test to arrive at a total cost including moving. This was half that of the two-pass system because it was split with the pulpwood phase of the one-pass system. Regression analysis was used to compare the cost per green ton with tonage per acre. The cost per green ton was not significantly different over the range of tonages tested. The average cost per green ton of the one-pass system with deck preparation was $7.80.

Conclusions

The two-pass harvesting system depended on the feller buncher. As energywood tonage decreased, the feller buncher productivity decreased. As feller buncher productivity decreased, the feller buncher cost increased. This increase in cost drove the system cost up as stand tonage decreased.

The one-pass harvesting system productivity and cost were not significantly different over the range of energywood tonages tested. This was due to the free energywood tonage gained from the pulpwood phase of the operation.

When the cost of moving was added to the total cost calculation it was seen that high tonage tracts carry this cost much better than low tonage tracts.

The one-pass system had lower costs per ton and utilized more of the energywood than the two-pass system. But, the two-pass system has the benefit of allowing the felled energywood to dry, thus increasing the BTU value.

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Table 1. Energywood and pulpwood tonages/acre.

Tract	Number of Passes	Tons /Acre Energywood Estimate	Energywood Actual	Pulpwood Actual
I	2	4.05	9.94	34.95
II	1	4.83	25.89	42.08
II	2	22.26	23.11	22.74
II	1	20.27	35.64	27.69
III	2	32.40	37.77	30.33
III	1	25.59	46.06	38.17
IV	2	34.63	36.81	30.94
IV	1	45.00	49.71	30.80
V	2	6.85	3.23	----
VI	2	6.74	3.15	----

Table 2. Component productivity for one- and two-pass harvesting operations.

Tract	Pass	Green Tons/Acre	Production in Green Tons/Productive Hour: Feller Buncher	Skidder	Chipper
VI	2	3.15	7.26	17.91	30.29
V	2	3.23	6.67	20.72	42.50
I	2	9.94	6.79	15.63	52.32
II	2	23.11	14.21	25.51	54.25
IV	2	36.81	12.68	17.83	45.22
III	2	37.77	13.71	24.49	62.33
I	1	25.89	20.45	29.76	40.45
II	1	35.64	19.10	25.83	58.05
III	1	46.06	21.56	27.22	53.56
IV	1	49.71	19.18	29.28	47.16

Table 3. System and component costs for one- and two-pass harvesting operations.

			Cost in Dollars/Green Ton				
Tract	Pass	Green Tons/Acre	Feller Buncher	Skidder	Chipper	System	System With Moving Cost
VI	2	3.15	8.02	2.92	2.66	13.60	19.95
V	2	3.23	8.74	2.50	1.90	13.14	19.33
I	2	9.94	8.59	3.34	1.55	13.48	15.48
II	2	23.11	4.10	2.06	1.49	7.65	8.51
IV	2	36.81	4.60	2.94	1.79	9.33	9.86
III	2	37.77	4.25	2.14	1.30	7.69	8.21
I	1	25.89	2.85	1.76	2.00	6.61	8.54
II	1	35.64	3.05	2.03	1.39	6.47	7.87
III	1	46.06	2.70	1.92	1.51	6.14	7.23
IV	1	49.71	3.04	1.79	1.71	6.55	7.56

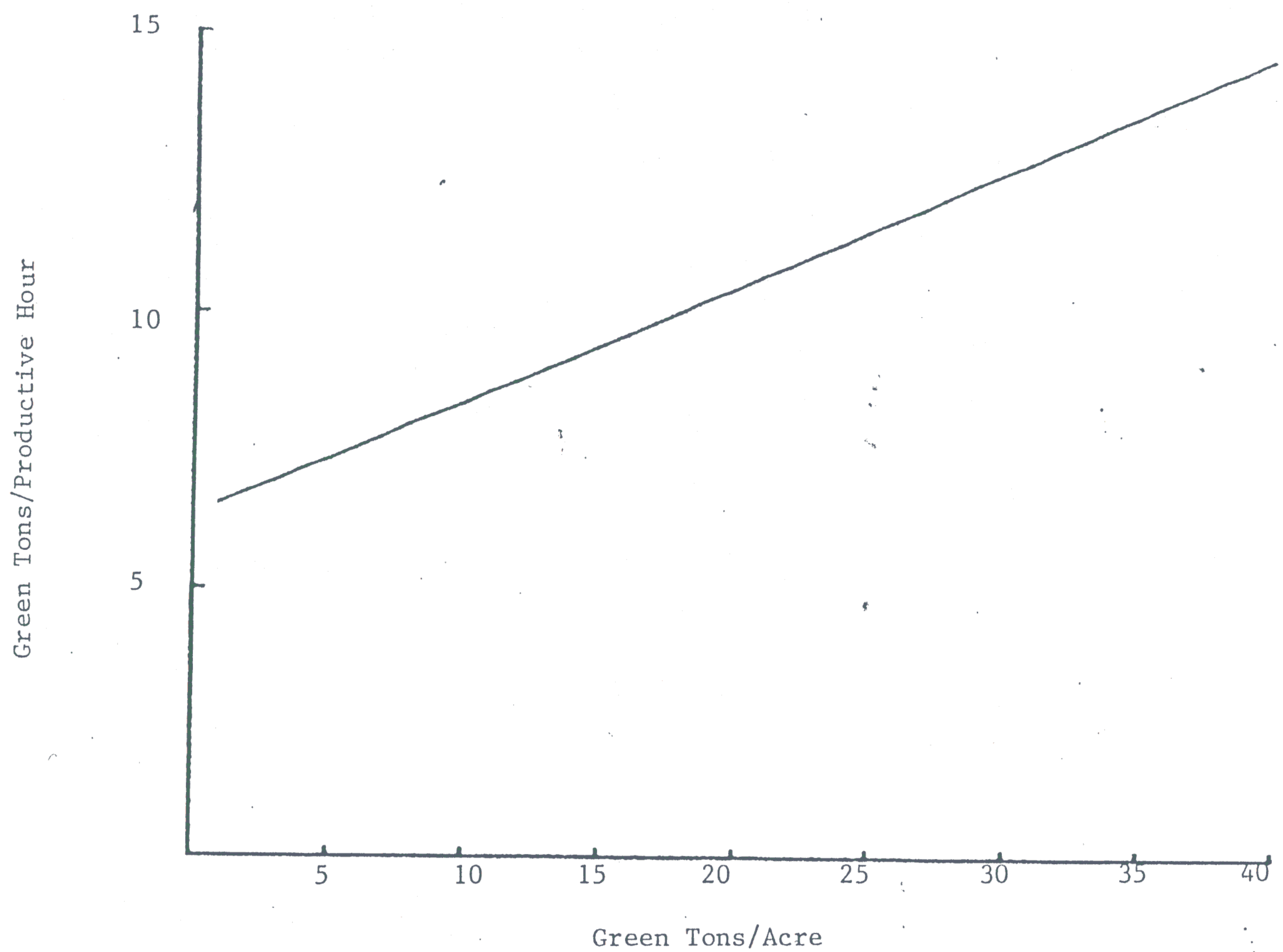

Figure 1. Feller buncher productivity (two-pass).

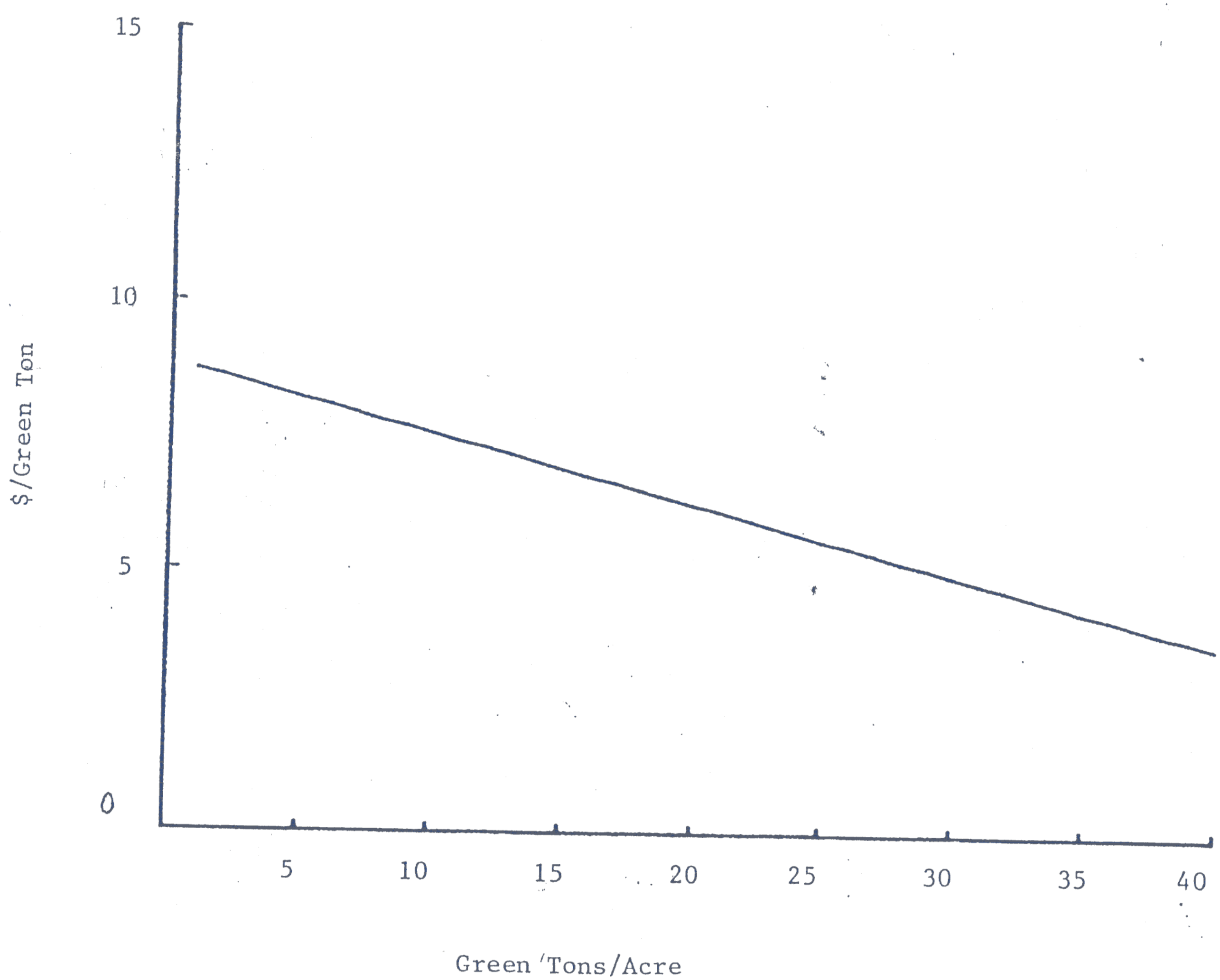

Figure 2. Feller buncher cost (two-pass).

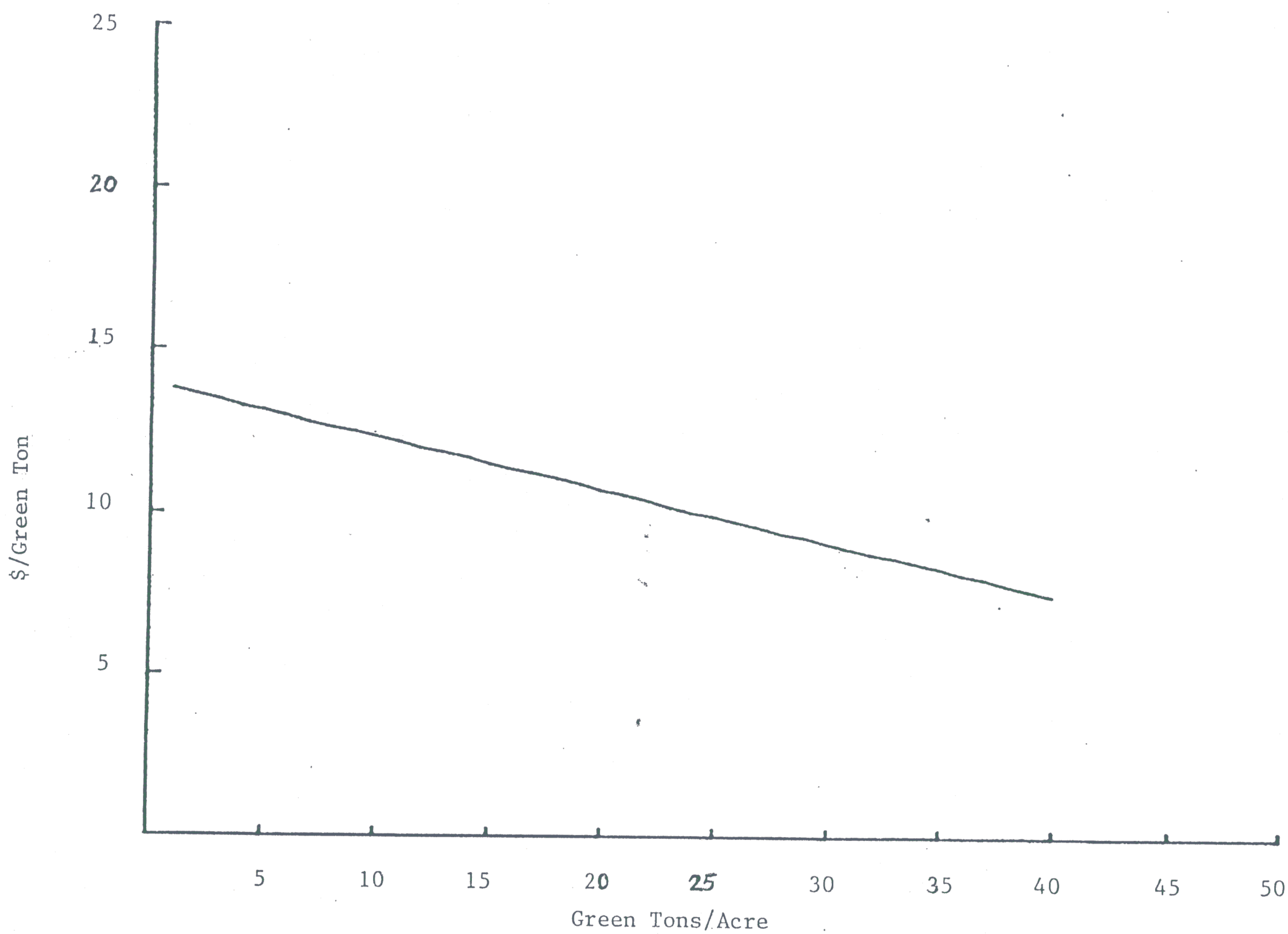

Figure 3. Cost per green ton without moving cost (two-pass).

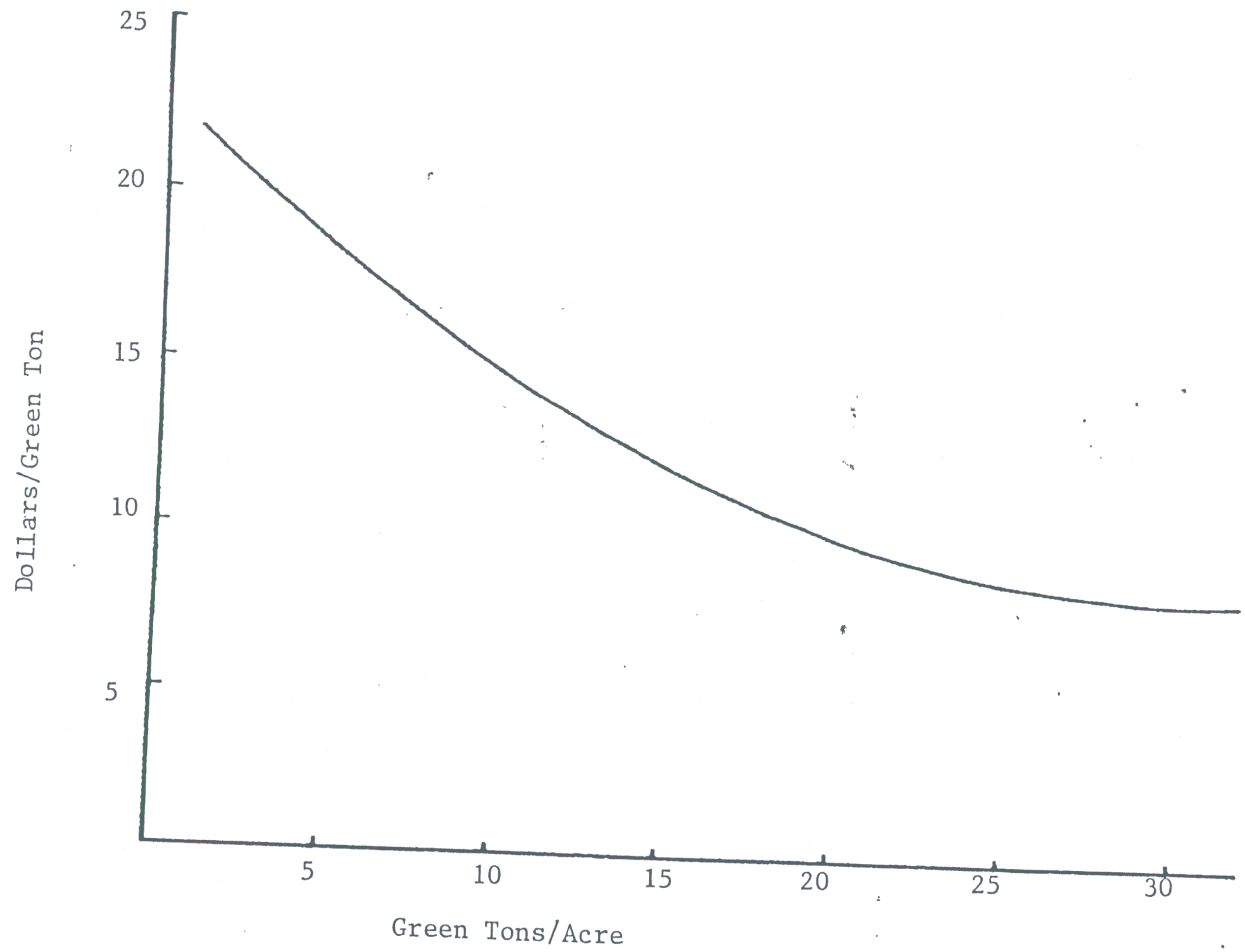

Figure 4. Cost per ton with moving cost (two-pass).